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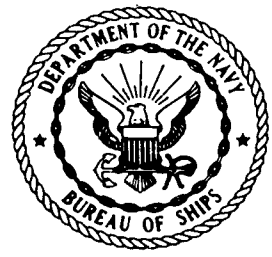
SEALS FOR 12,500 PSIG AIR SYSTEMS

FIRST PROGRESS REPORT

Report No. 28-11

RUBBER LABORATORY

MARE ISLAND NAVAL SHIPYARD



TECHNICAL REPORT

12ND P2321

SEALS FOR 12,500 PSIG AIR SYSTEMS

FIRST PROGRESS REPORT

Report No. 28-11

Project No. S-F013-13-01

Task No. 907

Identification No. 79-907-7

RUBBER LABORATORY

MARE ISLAND NAVAL SHIPYARD

VALLEJO, CALIFORNIA

Prepared 26 June 1963

ABSTRACT

The ability of Viton B O-rings to seal 12,500 psig nitrogen pressure was evaluated under dynamic and static simulated service conditions using spiral Teflon back-up rings. The static O-ring seals in the three test devices used leaked badly after 15-1/2, 19, and 46-1/2 hours, respectively, under pressure. Examination of the O-rings after test showed that their surfaces were permanently distorted in the area which contacted the back-up rings at and between the ends of the spiral. No other irregularities or evidences of extrusion were observed on the O-ring surfaces. The leakage may have been due to the distortion of the O-ring surface caused by the use of the spiral back-up rings.

Swell of the O-rings due to dissolving of nitrogen gas in the rubber was only 4.4% measured after 4 days exposure to 12,500 psig nitrogen pressure, and no blisters were observed in the O-rings after this test.

For future tests, it is proposed to retest the sealing ability of the Viton B O-rings under 12,500 psig air pressure using solid Teflon back-up rings.

REFERENCES

(a) BUSHIPS ltr F013 13 01, Ser 634C1-499 of 24 May 1962
(b) BUSHIPS ltr F013 13 01, Ser 634C1-692 of 14 Jul 1961
(c) Military Specification MIL-G-23652 (SHIPS) of 28 Mar 1963; "Gasket and Packing Material Petroleum and Phosphate Ester Fluid Resistant"
(d) BUSHIPS ltr F013 13 01, Ser 634C1-846 of 5 Sep 1962
(e) NAVSHIPYD MARE Rubber Laboratory Report 28-10 of 10 July 1962; "Seals for 5200 psi Air Systems. Final Report"
(f) NAVSHIPYD MARE Rubber Laboratory Report 28-9 of 5 Mar 1962; "Seals for High Pressure Air Systems in Submarines. Progress Report No. 7"

INTRODUCTION

1. The Rubber Laboratory was requested by the Bureau of Ships in reference (a) to develop seals for 12,500 psig air pressure, as outlined in reference (b). The work assigned included the development of a specification for the seals. The test requirements and procedures were to parallel those for Type II of specification MIL-G-23652, reference (c). Reference (d) stated that shipboard air systems operating at pressures higher than 5200 psig will not use petroleum or phosphate-ester lubricants in the compressor. The seals for use in 12,500 psig air systems are therefore not required to be resistant to these fluids.

2. This is the first progress report of this investigation. It describes the testing of Viton B O-rings for ability to seal 12,500 psig nitrogen pressure under dynamic and static conditions. The swelling of the O-rings by nitrogen at 12,500 psig pressure was also measured.

SEALS TESTED

3. The seals tested were O-rings made from Rubber Laboratory stock 377-112, a Viton B stock meeting the requirements of specification MIL-G-23652, Type II. Type II requirements are for seals suitable for use in 5,200 psig air systems. The stock was developed for this service by the Rubber Laboratory, as described

in Report 28-10, reference (e). The recipe and cure employed in manufacturing the O-rings are given below:

Stock 377-112

Viton B	100
Thermax	10
Philblack E	15
Maglite D	15
Stearic acid	0.2
Di-isooctyl sebacate	3
Diak No. 3	4

CURE: 30 min. at 300°F in press, plus 1 hr. each at 200°, 250°, 300°, 350°, and 400°F in oven, plus 24 hrs. at 450°F in oven

TESTING PROCEDURE

4. The apparatus for testing the ability of the O-rings to seal 12,500 psig gas pressure is shown in a cross sectional drawing, Appendix 1, and in a photograph, Appendix 2. The apparatus consisted of a hollow cylinder, a cap for each end of the cylinder, and a piston designed to slide inside the cylinder. All parts were made of corrosion-resistant steel. The cylinder had a circumferential groove at each end wherein the O-rings for static testing were installed. The piston had a circumferential groove at each end wherein the O-rings for dynamic testing were installed. All grooves were wide enough for Teflon back-up rings. The latter rings were installed on the low pressure side of the O-rings to prevent the O-rings from being extruded through the down-stream clearance.

5. The O-rings on the cylinder were AN-6230-7 type with a nominal cross sectional diameter of 0.139±.004 inch and a nominal internal diameter of 2.359±.010 inches. The O-rings on the piston were AN-6227-27 type with a nominal cross sectional diameter of 0.139±.004 inch and a nominal internal diameter of 1.484±.006 inches. The depths of the grooves in the cylinder and piston were designed to yield 8% compression of O-rings having the minimum allowable cross sectional diameter. The measured diametric clearance was 3 to 5 mils between the cylinder and the end caps, and between the piston and the cylinder.

6. The apparatus was operated by applying nitrogen under 12,500 psig pressure to the ends of the cylinder through the holes in the caps. The dynamic and static seals were thus pressurized simultaneously. Movement of the piston was effected by establishing a pressure differential between the two ends.

7. Nitrogen rather than air was used in the tests described herein because instructions from the manufacturer of the compressor indicated a possibility of explosion if air were used. Since air is approximately 80% nitrogen, it was felt the use of nitrogen would give about the same results as would air. Subsequent information from the compressor manufacturer indicated that the compressor can be safely used to compress air; therefore air will be used for all future tests. The compressor was Model 3033 manufactured by the Pressure Products Industries, Hatboro, Pennsylvania.

8. Three test apparatuses were used. Before assembling each apparatus, the O-rings to be tested and the walls of the cylinders were wiped with Molykote, a molybdenum disulfide powder manufactured by the Alpha Corporation, Greenwich, Connecticut. The O-rings and spiral Teflon back-up rings were installed in the grooves with the back-up rings on the low pressure side of the O-rings, as shown

in Appendices 1 and 2. Spiral Teflon back-up rings are usually used with high pressure seals because they can be easily installed without disassembly of the O-ring groove. Solid Teflon back-up rings are not generally employed because they cannot be stretched or threaded to fit into the O-ring grooves. The grooves must therefore be specially designed so that they can be disassembled to permit installation of the back-up rings.

9. The three apparatuses were assembled and connected to the compressor. The apparatuses were immersed in water so that any leaks occurring during testing would be readily apparent. Appendix 3 is a photograph of the compressor and the three assembled apparatuses in position for the test.

10. The sequence of pressure application and release is given below.

a. Nitrogen at 12,500 psig was applied first to one end of each test device and then immediately to the other. These ends are identified hereinafter as ends A and B, respectively. The piston was therefore initially at end B, being forced there by the pressure at end A.

b. After 30 minutes, end B and end A were exhausted in quick succession. The piston remained at end B. Approximately 7 seconds were required to exhaust end B and 20 seconds were required to exhaust end A.

c. After 15 seconds, 12,500 psig nitrogen was applied to end A and then to end B. The piston remained at end B.

d. End A was exhausted to allow the piston to be forced to end A by the 12,500 psig pressure in end B. End A was then repressurized. The piston remained at end A.

e. After 30 minutes the procedures in paragraphs b, c, and d were repeated except that the piston was initially at end A and was moved to end B.

f. On all subsequent cycles, the procedures were alternated in order to move the piston back and forth.

g. The test was continued for 8-1/2 hours per day, five days per week until failure occurred as evidenced by continuously escaping gas. The devices were maintained at 12,500 psig overnight and weekends.

NITROGEN SWELL TESTS

11. The volume change after exposure to 12,500 psig nitrogen pressure for 96 hours at 60-70°F was measured by the procedure described in specification MIL-G-23652, except that the time to lower the pressure from 12,500 psig to 0 psig was necessarily longer. Fifteen seconds were required to lower the pressure to 4,000 psig, one minute to 1,000 psig, and a total of 2.3 minutes to 0 psig.

RESULTS

Pressure-Cycling Test

12. The test devices showed large-volume continuous leakage after 31, 38, and 93 cycles, respectively, corresponding to the respective times of 15-1/2, 19, and 46-1/2 hours under 12,500 psig pressure.

13. Before the large-volume leakage occurred, the first two devices invariably leaked at the rate of 6 to 10 small bubbles per minute at the end of the first cycle after having been under static pressure overnight or over a weekend. This minor leakage continued until after the second cycle when it ceased for the remainder of the cycles for that day. The third device showed no leakage until the large volume leakage occurred.

14. It was observed that all of the leakage came from the static O-rings on the cylinders rather than from the O-rings on the pistons. Examination of the O-rings after test revealed no major defects and no evidence of extrusion of the O-rings. The only discontinuity observed in the surface of each O-ring was a permanent distortion in the area which contacted the spiral back-up rings at and between the ends of the spiral. Appendix 4 is a photograph showing one of the O-rings and back-up rings in position in the groove of the cylinder after the test. The distortion of the O-ring due to being forced between the ends of the spiral-cut back-up ring and the flattening of the back-up ring against the side of the groove are evident. Appendix 5 is a photograph of an O-ring after test showing the permanent distortion of the O-ring due to its contact with the back-up ring at the ends of the spiral.

15. The swell of the O-ring after 4 days under 12,500 psig nitrogen pressure was only 4.4%, as compared with the maximum of 10% allowed by specification MIL-C-23652 for seals designed for use under 5,200 psig air pressure.

16. The cause of leakage could not be determined with certainty. It is believed that the distortion of the O-ring due to its contact with the spiral back-up ring at and between the ends of the spiral may have been responsible. This distortion may have reduced the compression of the O-ring at this point sufficiently to permit leakage. The use of solid Teflon back-up rings would eliminate this possible cause of leakage.

FUTURE WORK

17. The following is proposed for future work:

    a. Redesign the test device to permit the use of solid Teflon back-up rings.

    b. Test the Viton B O-rings in the redesigned test device under 12,500 psig air pressure using solid, Teflon back-up rings.

    c. Investigate the effects of time and air pressure on the swell of Viton B O-rings.

    d. Determine the effect of aging in oxygen at 1,800 psig on tensile properties of the Viton B O-rings. This will simulate the aging of O-rings in 12,500 psig air.

PERSONNEL

Bureau of Ships Project Engineer: W. S. Bourn

Tests conducted by: J. M. Holloway, Technologist

Report prepared by: A E Barrett
A. E. Barrett, Supervisory Technologist

Approved by: R E Morris
R. E. Morris, Head, Rubber Laboratory

APPENDICES

1. Drawing. Cross-sectional view of device for static and dynamic sealing tests of O-rings for high pressure air service.

2. Photograph. Assembled and disassembled apparatus for testing ability of O-rings to seal 12,500 PSI gas pressure under static and dynamic conditions (MSA-59218-5-63).

3. Photograph. Compressor and O-ring sealing test apparatus in position for testing under 12,500 PSI gas pressure (MSA-59217-5-63).

4. Photograph. Viton B(377-112) O-ring in test device after 47 hours under 12,500 PSI nitrogen pressure showing distortion at back-up ring overlap. Magnification 10X. (MSA-59213-5-63)

5. Photograph. Viton B(377-112) O-ring after 47 hours under 12,500 PSI nitrogen pressure showing distortion at back-up ring overlap. Magnification 10X. (MSA-59214-5-63)

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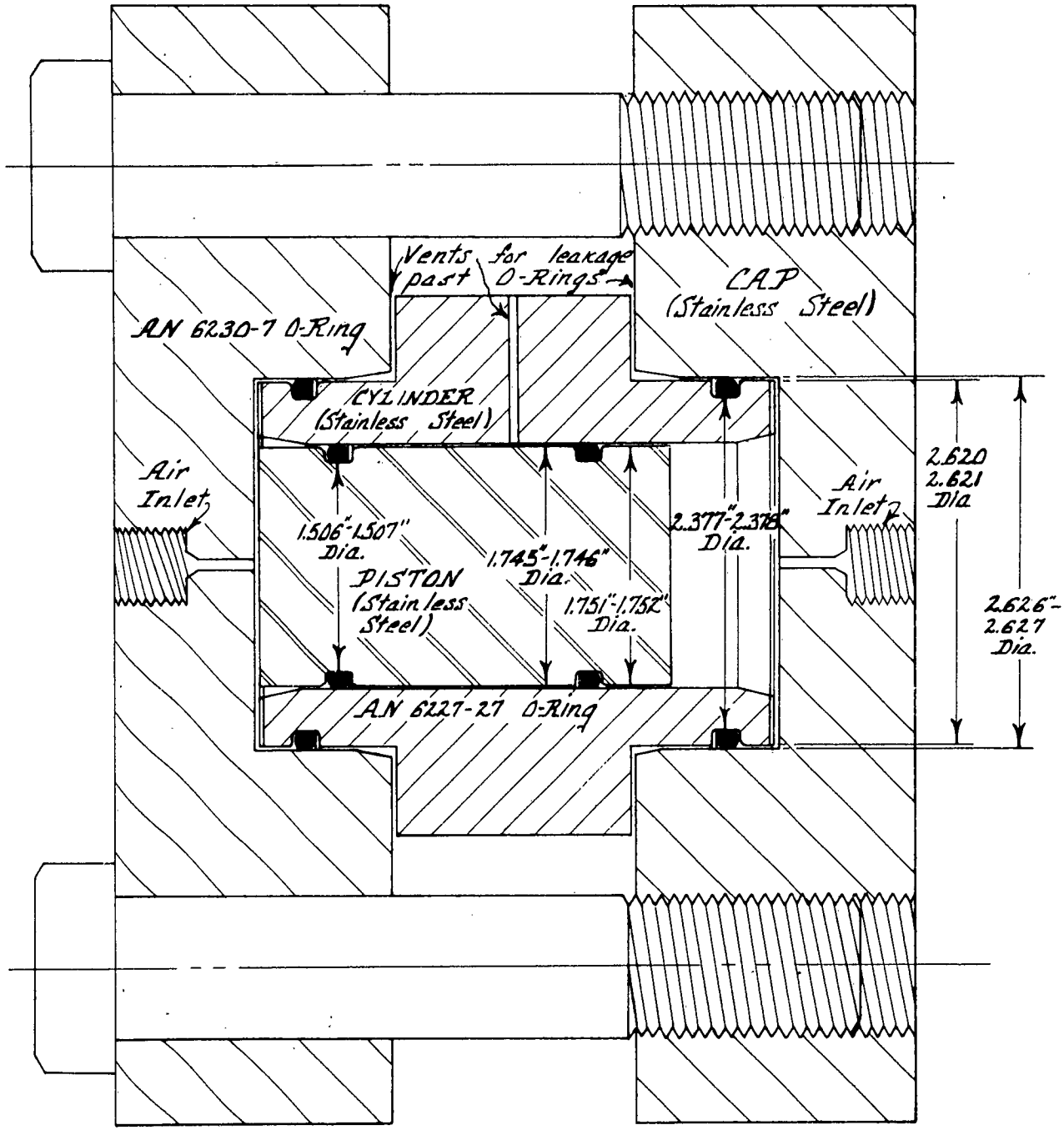
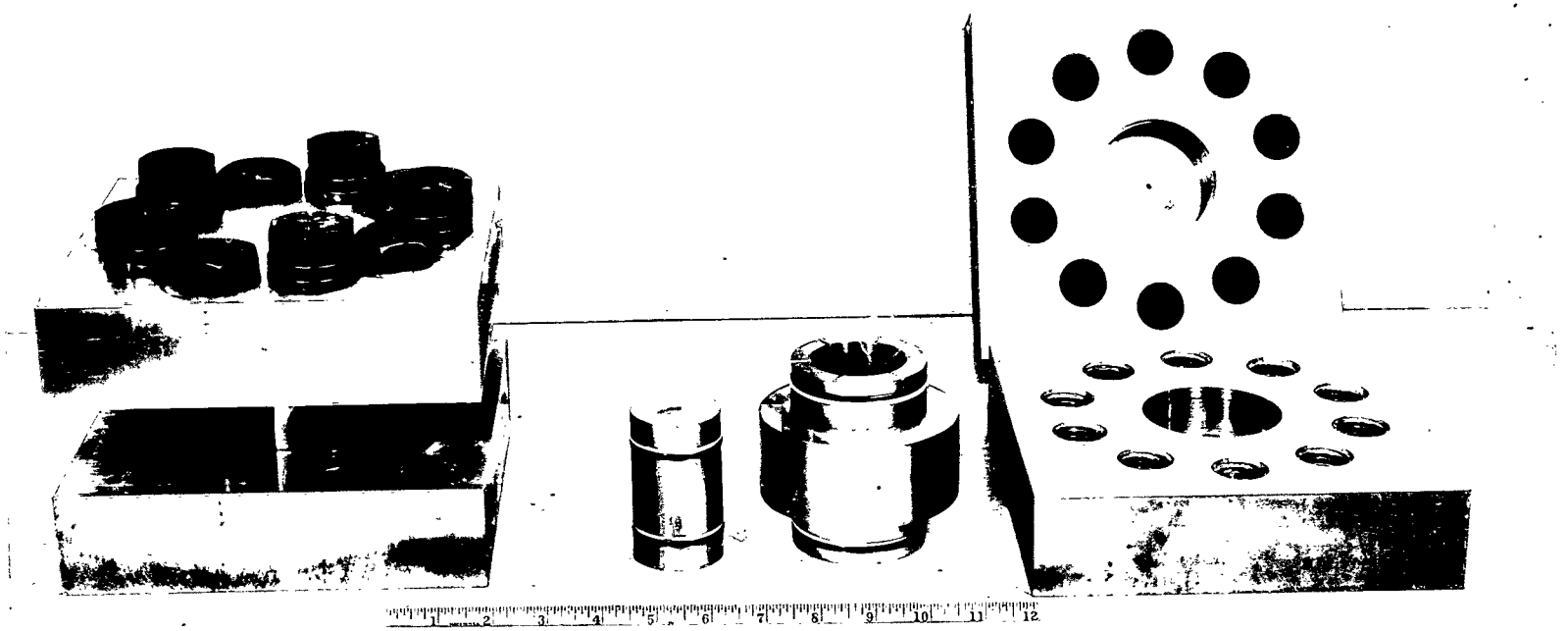
Abstract cards

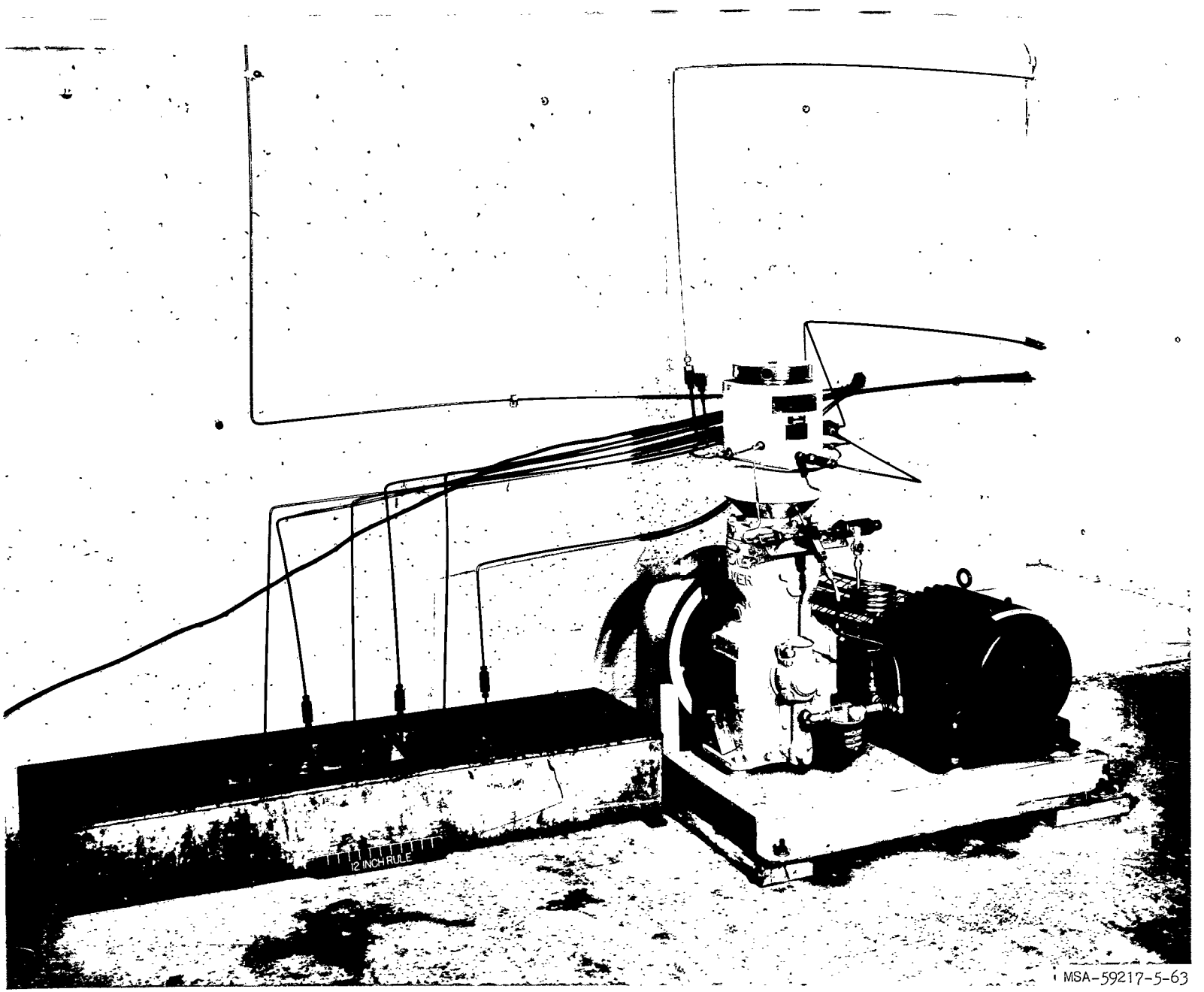


CROSS-SECTIONAL VIEW OF DEVICE FOR STATIC AND DYNAMIC SEALING TEST OF O-RINGS FOR HIGH PRESSURE AIR SERVICE

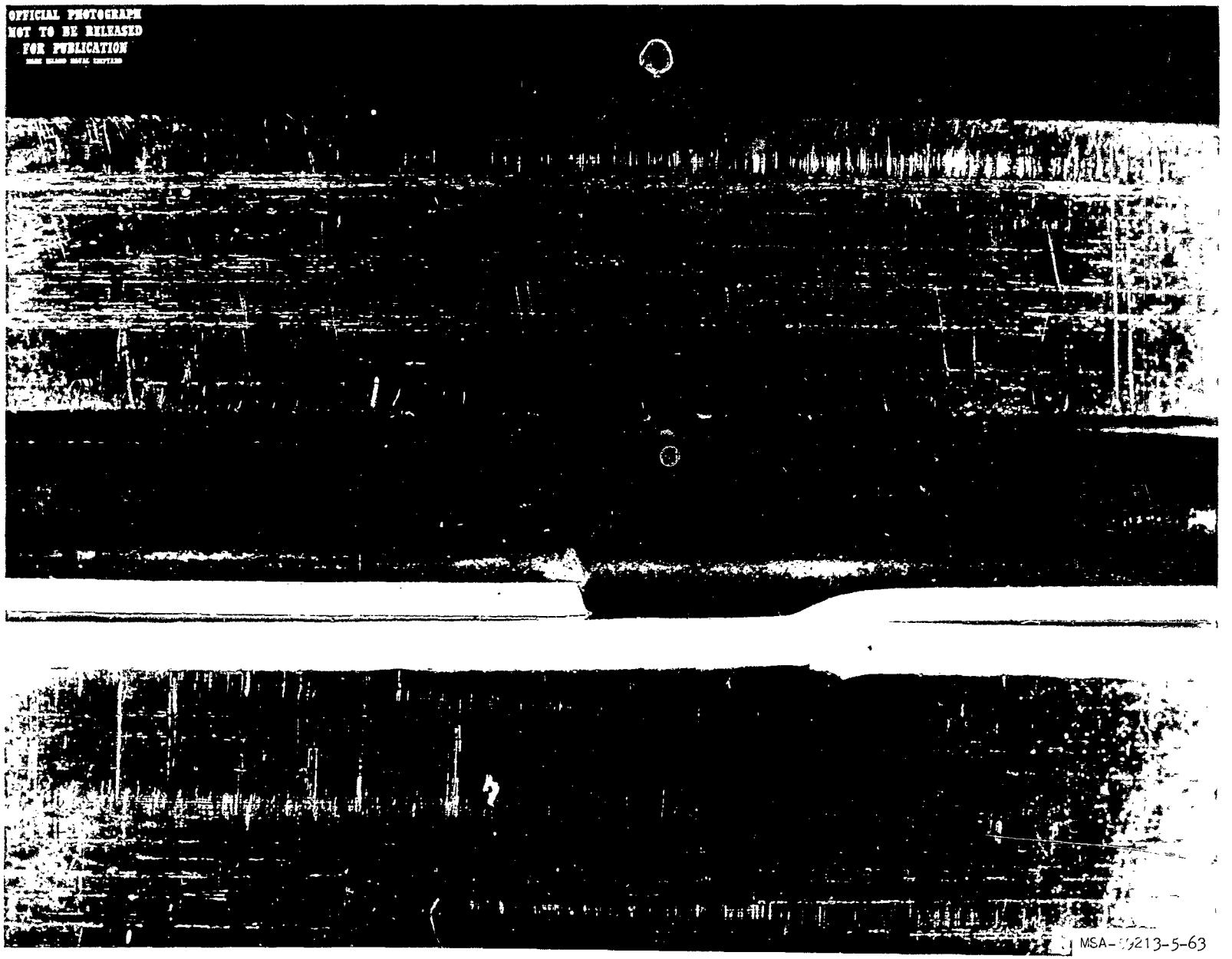


MSA-59218-5-63

Assembled and Disassembled Apparatus for Testing Ability of O-rings
to Seal 12,500 PSI Gas Pressure under Static
and Dynamic Conditions.



COMPRESSOR AND O-RING SEALING TEST APPARATUS IN POSITION FOR TESTING UNDER 12,500 PSI GAS PRESSURE.



VITON B(377-112) O-RING IN TEST DEVICE AFTER 47 HOURS UNDER 12,500 PSI NITROGEN PRESSURE SHOWING DISTORTION AT BACKUP RING OVERLAP. MAGNIFICATION 10X.

MSA-59214-5-03

VITON B(377-112) O-RING AFTER 47 HOURS UNDER 12,500 PSI NITROGEN
PRESSURE SHOWING DISTORTION AT BACKUP RING OVERLAP.
MAGNIFICATION 10X.

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